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To Professor Asa Gray, M.D.
With the Author's Compliments

ON

SOME ABNORMAL CONES

OF

PINUS PINASTER.

BY

ALEXANDER DICKSON, M.D., EDIN. & DUBLIN,

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XIX.—*On some Abnormal Cones of* Pinus Pinaster. By ALEXANDER DICKSON, M.D., Edin. & Dublin.; Regius Professor of Botany in the University of Glasgow. (Plates XIX.–XXII.)

(Paper read 1st May 1871. Given in for publication 23d October 1871.)

It is well known that although the overwhelming majority of specimens of fir cones exhibit one or other of the simple spiral arrangements represented by the terms of the ordinary series $\frac{1}{2}, \frac{1}{3}, \frac{2}{5}, \frac{3}{8}, \frac{5}{13}$, &c., whose generating and successive secondary spirals are indicated by the numbers 1, 2, 3, 5, 8, 13, &c., yet exceptional cases occur now and again, where we find either conjugate spirals of the ordinary system, or arrangements (usually simple, but sometimes conjugate) belonging to other systems of spirals. Of these exceptional arrangements, perhaps the most common are bijugates of the ordinary system, giving the numbers 2, 4, 6, 10, 16, 26, &c., and simple spirals belonging to the system $\frac{1}{3}, \frac{1}{4}, \frac{2}{7}, \frac{3}{11}, \frac{5}{18}$, &c., giving the numbers 1, 3, 4, 7, 11, 18, &c. More rarely, trijugates of the ordinary system occur, giving the numbers 3, 6, 9, 15, 24, 39, &c.; or spirals of the system $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}, \frac{8}{37}$, &c., giving the numbers 1, 4, 5, 9, 14, 23, 37, &c.; not to speak of various other arrangements, some of which will fall to be considered in the special cases which form the subject of the present communication.

The occurrence of exceptional arrangements in structures exhibiting so much general uniformity as fir cones, naturally raises the question as to whether these deviations may not be deduced from the simple spiral of the ordinary system, or from some fundamental form, affording a common basis for both.

In his great work on the Arrangement of the Scales on Fir Cones, ALEXANDER BRAUN, in speaking of the occasional occurrence of cones where the most apparent secondary spirals, instead of being, as usual, 5 and 8 in number, are 4 and 7, refers to the temptation to explain away the anomaly by assuming the abortion of the fifth and eighth secondary spirals respectively, only, however, to reject such an assumption as an absurdity of the same kind, as if 2-nary, 4-nary, and 7-nary flowers were considered respectively as 3-nary, 5-nary, and 8-nary ones reduced by abortion; adding, that "it will be better

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calmly to pursue the investigation, rejecting all premature hypotheses, which can never be more than substitutes for science."*

In their essay on the arrangement of curviserial leaves, the brothers BRAVAIS approach this question somewhat more closely. In dismissing the idea of abortion in such cases, BRAUN occupied his position mainly, it would appear, in consequence of the absence of any supporting evidence. The celebrated French authors, on the other hand, actually observed, in capitula of *Dipsacus* and in fir cones, certain cases where, in the same inflorescence, there occurred an actual change from one spiral system to another, accompanied by a diminution in the number of secondary spirals. They do not appear, however, to have had a very definite idea as to the exact manner in which this diminution in the number of secondary spirals is effected. Although on the whole they seem inclined to treat the phenomenon in question as the result of abortion of secondary spirals,—as, for example, when referring to certain capitula of *Dipsacus* with 16 and 26 as the numbers of the secondary spirals at the base, suddenly changing to 15 and 26, or 15 and 25, or 16 and 24, they state that here "there is no doubt as to the *abortion* of the missing spirals, since they are as evident as their fellows at the base of the capitulum,"†—yet, in the *résumé* at the end of their essay, considerable uncertainty is indicated in the sentence, that "the *convergence* of two spirals into one is to be explained by partial *abortion* of one of the spirals, or, if preferred, by the *coalescence* of two spirals into one."‡

Of cases of this kind occurring in fir cones, MM. BRAVAIS describe two cones of *Pinus Pinaster* (*Pin maritime*), one where the lower part of the cone exhibited secondary spirals 7 S, 12 D (series $\frac{1}{2}, \frac{2}{5}, \frac{3}{7}, \frac{5}{12}, \frac{8}{19}$, &c.), while towards the apex the arrangement changed to 7 S, 11 D (series $\frac{1}{3}, \frac{1}{4}, \frac{2}{7}, \frac{3}{11}, \frac{5}{18}$, &c.);§ and a second, in which the lower four-fifths of the cone exhibited secondary spirals 9 S, 13 D (series $\frac{1}{4}, \frac{2}{9}, \frac{3}{13}, \frac{5}{22}$, &c.), while at the upper fifth the arrangement changed, by suppression of one of the spirals by 9, to 8 S, 13 D (ordinary series $\frac{1}{2}, \frac{1}{3}, \frac{2}{5}, \frac{3}{8}$, &c.)‖. Such cases, along with some others, chiefly in capitula of *Dipsacus sylvestris*, lead MM. BRAVAIS into a discussion of the general question of the transition from one arrangement to another, involving a change in the number of secondary spirals. As regards their "curviserial" forms,

* BRAUN, Vergleichende Untersuchungen über die Ordnung der Schuppen an den Tannenzapfen; Nova Acta Acad. C.L. xv. 1, p. 316.

† L. et A. BRAVAIS, Sur la disposition des feuilles curviseriées. Ann. des Sc. Nat. 2me sér. vii. p. 100.

‡ *L. c.* pp. 106, 107. § *L. c.* p. 93. ‖ *L. c.* p. 103.

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however (under which they include such arrangements as those in fir cones), they are disposed to admit the occurrence only of such transitions as take place by way of "*convergence*" of secondary spirals, resulting in *diminution* of number. For example, after referring to the possible derivation of an arrangement with 5 and 7 secondary spirals (series $\frac{1}{2}, \frac{2}{5}, \frac{3}{7}, \frac{5}{12}$, &c.) from an ordinary one with 5 and 8, by abortion of one of the spirals by 8, and adding that "the series 1, 4, 5, 9 . . . . . $\left[\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}\right.$, &c.$\left.\right]$, does not admit of explanation by the way of abortion, and that one can deduce it from the ordinary series only by supposing a *superfœtation*, or addition of a new spiral, among the secondary spirals by 8," they continue, "This hypothesis appears to us altogether improbable, since, in the face of an immense number of instances where two spirals converge into one, we cannot, on the other hand, cite one (apart from rectiserial stems), where one spiral *diverges* into two similar and parallel ones."*

Not having any strong belief in the fundamental distinction between the "curviserial" and "rectiserial" forms of these authors, and knowing that "divergence" or bifurcation of vertical rows (which are, in one sense, to be regarded only as the steepest secondary spirals) is not very rare in "rectiserial" *Cacti* and succulent *Euphorbiæ*, I have not been surprised to encounter, as I have done, cases of "divergence" of secondary spirals in fir cones. In the following remarks, however, I shall treat chiefly of the "*convergence*" of secondary spirals, a phenomenon which, I think, I shall be able to explain more definitely than has hitherto been done; reserving to a future occasion more extended reference to the phenomenon of "*divergence*" of spirals.

For some of the cones to be described, I am indebted to the kindness of R. Smyth, Esq., Emyvale, county Monaghan, Ireland; others I obtained in the woods at Muirhouse (seat of H. Davidson, Esq.), near Edinburgh; further, I am indebted to Professor Balfour for permission to examine the collection of cones in the Museum at the Royal Botanic Garden, Edinburgh, where I found the remarkable cone of *P. lambertiana*, which was lately exhibited before the Society,† and to which I shall recall attention in the following remarks, as also a cone of *P. Pinaster*, with $\frac{5}{22}$ spiral, which was exhibited on the same occasion, and of which I give an outline figure in Plate XX. fig. 8.

I shall, in the first place, give a brief description of the cones forming the subject of the present paper; after which we shall be in a position to judge of and discuss the bearings of the abnormal phenomena.

I. Cone of *P. Pinaster*—Mr Smyth—(Plate XX. figs. 1 and 2; Plate XXI. fig. 1). Length of cone $5\frac{1}{4}$ inches. At the base there is a right-handed $\frac{8}{37}$

* *L. c.* pp. 104, 105.

† See Proceedings R. S. Edin., vii. pp. 398, 399.

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spiral (series $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}, \frac{8}{37}$, &c.), with secondary spirals 9 S, 14 D, 23 S. A little above the base, however, two of the nine spirals to the left "converge" into one, leaving, from that point up to about the middle of the cone, an arrangement with secondary spirals 8 S, 14 D, 22 S, = a left-handed bijugate of the series $\frac{1}{3}, \frac{1}{4}, \frac{2}{7}, \frac{3}{11}, \frac{5}{18}$, &c., whose two fundamental spirals have each the divergence $\frac{5}{18 \times 2}$. About the middle of the cone, two of the fourteen spirals to the right converge into one, leaving from thence to the top of the cone an arrangement of secondary spirals 8 S, 13 D, 21 S, = a left-handed $\frac{13}{34}$ spiral of the ordinary series $\frac{1}{2}, \frac{1}{3}, \frac{2}{5}, \frac{3}{8}, \frac{5}{13}, \frac{8}{21}, \frac{13}{34}$, &c. The following table (where the three regions are roughly termed "top," "middle," and "bottom") will render the arrangement intelligible:—

TABLE A.*—*Cone of* Pinus Pinaster.

	S	D	S	D	S	D	S	V
Top,	1	2	3	5	8	13	21	$34 = \frac{13}{34}$
Middle,	—	—	2	6	8	14	22	$36 = \frac{5}{18 \times 2}$
Bottom,	—	1	4	5	9	14	23	$37 = \frac{8}{37}$

II. *P. Pinaster*—Mr SMYTH—(Plate XIX. fig. 1; Plate XX. fig. 3; Plate XXI. fig. 2). Length of cone $5\frac{3}{4}$ inches. From the base to near the top there is a right-handed $\frac{5}{18}$ spiral (series $\frac{1}{3}, \frac{1}{4}, \frac{2}{7}, \frac{3}{11}, \frac{5}{18}$, &c.), with secondary spirals, 4 D, 7 S, 11 D. Near the top of the cone, however, two consecutive scales in one of the spirals by 4 to the right (adjacent scales of two of the spirals by 7 to the left) have partially coalesced, giving beyond that point an arrangement of secondary spirals 4 D, 6 S, 10 D, = a left-handed bijugate of the ordinary series, whose two fundamental spirals have each the divergence $\frac{3}{8 \times 2}$. The following table represents the arrangement:—

TABLE B.—*Cone of* P. Pinaster.

	D	S	D	S	D	V
Top,	—	2	4	6	10	$16 = \frac{3}{8 \times 2}$
Bottom,	1	3	4	7	11	$18 = \frac{5}{18}$

* In this and the following tables, under S, are indicated the numbers of spirals, generating as well as secondary, running to the *left*; under D, the numbers of those running to the *right*; while under V, are indicated the numbers of vertical rows.

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III. *P. Pinaster*—Muirhouse—(Plate XX. figs. 4 and 5; Plate XXII. fig. 1). Length of cone $3\frac{1}{3}$ inches. Some scales on one side are somewhat damaged, by having been bitten, apparently before the cone was mature. The lower third of this cone exhibits a left-handed trijugate of the ordinary system, with secondary spirals 6 D, 9 S, 15 D, 24 S, and whose three fundamental spirals have each the divergence $\frac{5}{13 \times 3}$. Two of six spirals to the right "converge" into one, producing in the middle third of the cone the arrangement 5 D, 9 S, 14 D, 23 S, = a right-handed $\frac{8}{37}$ spiral (series $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}, \frac{8}{37}$, &c.). In the upper third of the cone, we have two further changes: in the first place, two of the nine spirals to the left "converge" into one, giving the arrangement 5 D, 8 S, 13 D, = a left-handed spiral of the ordinary series, probably $\frac{13}{34}$; and then, a little higher up, two consecutive scales of one of the spirals by 5 to the right (adjacent scales of two of the spirals by 8 to the left) have partially coalesced, almost precisely in the same way as the two scales near the top of the last cone, giving beyond that, up to the top of the cone, the arrangement 5 D, 7 S, 12 D, = a right-handed spiral of the series $\frac{1}{2}, \frac{2}{5}, \frac{3}{7}, \frac{5}{12}, \frac{8}{19}$, &c., probably $\frac{13}{31}$.

The changes in this very complicated cone are shown in the following table:—

TABLE C.—*Cone of* P. Pinaster.

	S	D	S	D	S	D	S	V
Top,	—	1	2	5	7	12	19	$31 = \frac{13}{31}$
Below Top,	1	2	3	5	8	13	21	$34 = \frac{13}{34}$
Middle,	—	1	4	5	9	14	23	$37 = \frac{8}{37}$
Bottom,	—	—	3	6	9	15	24	$39 = \frac{5}{13 \times 3}$

IV. *P. Pinaster*—Muirhouse—(Plate XX. figs. 6 and 7; Plate XXII. fig. 2). Length $4\frac{1}{2}$ inches. In this cone, nine secondary spirals to the left run continuously from near the bottom to the top. At the very bottom, there is a considerable amount of irregularity, some of the scales being of exceptional size and shape. It is probable, however, that were it not for the mal-development, the arrangement here would be a $\frac{7}{16}$ spiral, similar to what we meet further up on the same cone. However this may be, a "divergence" distinctly takes place of one secondary spiral into two, which form members of a set of eight running to the right. Thus the first arrangement which we can legitimately

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determine in this cone is one with secondary spirals 8 D, 9 S, = a left-handed $\frac{2}{17}$ spiral (series $\frac{1}{8}, \frac{1}{9}, \frac{2}{17}$, &c.). This spiral is continued through between 40 and 50 scales of the cone, when two of the eight secondary spirals to the right converge into one, giving us the arrangement 7 D, 9 S, = a right-handed $\frac{7}{16}$ spiral (series $\frac{1}{2}, \frac{3}{7}, \frac{4}{9}, \frac{7}{16}$, &c.), which, after being continued through between 20 and 30 scales, gives place to a left-handed trijugate of the ordinary series, with divergence $\frac{2}{5 \times 3}$, by two of the spirals by 7 becoming replaced by one of a set by 6. Neglecting the very bottom of the cone, we have the changes represented in the following table :—

TABLE D.—*Cone of* P. Pinaster.

	D	S	D	S	V
Top,	—	3	6	9	$15 = \frac{2}{5 \times 3}$
Middle,	1	2	7	9	$16 = \frac{7}{16}$
Bottom (a little above the)	—	1	8	9	$17 = \frac{2}{17}$

V. *P. Pinaster*—Muirhouse—(Plate XIX. fig. 3). Length of cone $3\frac{1}{3}$ inches. The upper part of this cone exhibits a left-handed $\frac{8}{21}$ (or possibly $\frac{13}{34}$) spiral. Carrying the eye downwards, however, we begin to observe, a little below the middle, rudimentary scales of small size and somewhat peculiar shape, intercalated with considerable regularity among the others, so as to appear as projections placed between the angles of the larger scales. As the base is approached, the scales in the downward continuation of the larger series become gradually reduced in size, till they are practically indistinguishable from the smaller ones; the general arrangement becoming, at the same time, so crowded and confused as to render precise determination of the spiral impossible.

In addition to the above, I would recall attention to the abnormal cone of *Pinus lambertiana* which I exhibited to the Society on a former occasion. This cone is noteworthy, not only as showing a transition by *convergence* from a bijugate of the system $\frac{1}{2}, \frac{2}{5}, \frac{3}{7}, \frac{5}{12}$, &c., giving the numbers 4, 10, 14, &c., to a simple spiral of the system $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}, \frac{5}{23}$, &c., giving the numbers 1, 4, 5, 9, 14, &c., but also as showing a transition, conversely, by *divergence*, from the latter to the former.

The following table represents the arrangement :—

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TABLE E.—*Cone of* Pinus Lambertiana, *in Museum, Edinburgh Botanic Garden.*

	S	D	S	D	S	V	
Top,	1	4	5	9	14	23	$= \frac{5}{23}$
Middle,	—	2	4	10	14	24	$= \frac{5}{12 \times 2}$
Bottom,	1	4	5	9	14	23	$= \frac{5}{23}$

Having submitted the foregoing facts, I shall now proceed to consider:—

1*st*, in what the so-called *convergence* of secondary spirals really consists;

2*d*, what constitutes affinity of different spiral systems as regards their possible or actual derivation one from another; and

3*d*, whether it is possible to conceive of the varying spirals in fir cones, or in other plants, being mediately or immediately derived from some one fundamental arrangement in a given set of cases.

1*st*, As to the nature of "convergence" of secondary spirals. It cannot fail to strike the attentive observer that a certain absurdity is involved in the idea of coalescence, or fusion of two secondary spirals into one. Secondary spirals, it is to be remembered, have only a relative existence. For example, in a cone with an $\frac{8}{21}$ spiral the very same scales which constitute the eight secondary spirals running to the one hand, make up the thirteen running to the other. The same objection applies to "convergence" considered as the result of an abortion or suppression of a secondary spiral; for it is as difficult to conceive of the abortion of one spiral, which has only a relative existence, as of the fusion of two similarly circumstanced. To take a special case. About the middle of Cone III., described above, an ordinary trijugate changes by "convergence" into an $\frac{8}{37}$ spiral; but it would be quite as correct to say that coalescence (or abortion) occurred among the spirals by 15, or by 24, as among those by 6, &c. (see Plate XXII. fig. 1). MM. BRAVAIS appear to have felt this difficulty, but content themselves with arguing for the probability of the abortion occurring among the more apparent secondary spirals, where the successive insertions are in contact, as contrasted with the improbability of its occurrence among the less apparent secondary spirals whose insertions are not contiguous.

Having disposed of the hypotheses of *abortion* and *fusion* of secondary spirals, respectively,—hypotheses which are, in fact, little more than different attempts to express what is simply one of the results of a certain disturbance, viz., diminution in the number of secondary spirals,—we proceed to inquire if there are any facts to guide us in ascertaining the proximate cause of the disturb-

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ance itself. To do this we have only to look at the upper portion of Cones II. and III. In each of these a change is ushered in by the partial fusion of two adjacent scales. These scales may be viewed either as consecutive members of one secondary spiral, or as adjacent members of two parallel ones; as, however, their relative position is strictly defined by reference to the spiral in which they are consecutive members, which it cannot be by simple reference to any two parallel spirals in which they occur, the former description is that which must be adopted. In these cases it is impossible to doubt that *it is the coalescence or fusion of two consecutive scales in one of the secondary spirals which leads to or causes the general disturbance of the arrangement.* When such a disturbance takes place, a convergence of certain secondary spirals becomes prominently visible; but this convergence is not at all more real, although more apparent, than the convergence of other secondary spirals whose component members do not happen to be in contact. It will be noted, moreover, that this disturbance affects the numbers of all the secondary spirals, excepting only those among which the fusion of consecutive scales occurs; for example, in Cone II. consecutive scales in one of the spirals by 4 have coalesced, and it is these spirals by 4 alone which run continuously throughout the two systems without diminution in number. That a similar explanation legitimately applies to all cases of "convergence," even where the duplex nature of what I would term the *scale of convergence* is not demonstrable, I think few will be inclined to doubt.

At this point, I may now conveniently refer to the method to be adopted in numbering the scales on the cones exhibiting "convergence." From the circumstance of the "scale of convergence" resulting from the fusion of two adjacent scales which are usually at a considerable interval from each other on the generating or fundamental spiral, it is evident that the disturbance consequent thereon must, at the very least, extend to all the scales which would have been included between the numbers of the two scales which have coalesced, if, indeed, it does not involve a region of the cone extending both above and below the level of the scale of convergence. At first sight it might appear to be the simplest method to consider the scale of convergence as the point of passage from the one system to that succeeding it—as at once the last term of the lower system, and the first of the upper. Here we might reckon the scales in the lower system either up to the lower, or up to the higher, of the two components of the scale of convergence. In either way, however, we should encounter a difficulty; as in the former case a considerable number of scales would escape the reckoning, while in the latter the double enumeration of a considerable number of scales would be involved. The disadvantage of double enumeration also attaches to a method suggested to me by a friend, viz., to number the scales from below the level of the convergence, according to the spiral of the lower system, as far up as one can go above it, and from above

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that level, according to the spiral of the upper system, as far down as one can go below it. The method now to be described, and which I have employed in numbering the outline figures of the cones in Plate XX. figs. 1–7, and in the construction of the plans or diagrams of the same in Plates XXI. and XXII., although to a certain extent artificial and arbitrary, yet has the advantage of reducing to a minimum the number of doubtful or ambiguous scales. My procedure is as follows:—The arrangements above and below a given convergence are noted; then, in order to ascertain how the secondary spirals of two such arrangements would most naturally fit or run into one another, constructions of the two arrangements are made in such a way that the last term of the lower system coincides with the first (*i.e.*, No. 0) of the upper; or if either or both of the systems happen to be conjugate, one of the last terms, or of the first, or of each, as the case may be, is to be placed at the common point of the two systems. Further, the constructions are made so that those secondary spirals which correspond in number and direction in the two systems shall be continuous; these spirals being, as above indicated, those among which the fusion of consecutive scales has, or is presumed to have, occurred. To take an example. Supposing we have to join or fit together a $\frac{2}{17}$ spiral below, and a $\frac{7}{16}$ spiral above, as in Plate XXII. fig. 2; a construction is made of the lower spiral, and its last term is taken as the starting-point of the one above, which is thence constructed in such a way that the lines of its secondary spirals by 9 are continuous with the 9 in the arrangement below. The lines of the secondary spirals by 8 in the lower, and of those by 7 in the upper system, are now drawn (these being the lines among which the convergence is most apparent, and which, of course, have approximately the same direction), when the next proceeding is to join the 8 below to the 7 above, which is effected as follows:—the lower extremities of the seven upper lines are joined to the upper extremities of those seven of the eight below, which lie nearest them in the same direction. The upper extremity of the eighth or remaining lower line is then joined to the nearest (in the same direction) of the lower extremities of the seven above, when it becomes apparent that, in the construction, it is this last point which is the point of convergence, and, moreover, that this point corresponds to No. 6 of the upper system. The cone under examination is now taken, and the "scale of convergence" marked as No. 6 of the upper spiral. This upper spiral is now reckoned back to No. 0, up to which point, on the other hand, the scales of the lower spiral are continuously reckoned. When this has been done, it will be found, in the case before us, that *one* scale has been excluded from the enumeration; and, on turning to the construction, it will be seen that this scale occupies a position corresponding to a point where one of the junction

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lines between the upper seven and lower eight spirals happens to intersect one of the lines by 9 running continuously through the two systems in the other direction. In the case before us, there is only one such intersection; but, as we shall presently see, there may be two or more such points in similar associations of other spiral systems, which, in the same way, will be found to correspond in position to scales excluded from the enumeration; or, again, there may be no such intersections, in which case every scale in the cone can be included in the continuous enumerations. Again, it will be found that the different transitions differ in the value in the upper system to be attached to the scale of convergence. To illustrate the above, I may refer to the diagrams in Plates XXI. and XXII., with which the outline figures of the corresponding cones on Plate XX. may be compared. In doing so, it will only be necessary for me to indicate the spirals by their systems,—thus, 1, 2, 3, 5, 8, &c., or 1, 3, 4, 7, 11, &c., and so on,—the particular term of its series to which a given spiral belongs being quite immaterial as regards the present question. The unnumbered scales on the outline figures of the cones, and the intersections corresponding thereto in the diagrams, I have marked with asterisks. In Plate XXI. fig. 1, we have the system 1, 4, 5, 9, 14, &c., passing into the bijugate 2, 6, 8, 14, &c., with three intersections corresponding to three unnumbered scales on the cone, and No. 2′ of the upper system as the point or scale of convergence; also, this same bijugate 2, 4, 6, 8, 14, &c., passing into 1, 2, 3, 5, 8, 13, &c., with one unnumbered scale, and No. 6 of the new system as the scale of convergence. In Plate XXI. fig. 2, the system 1, 3, 4, 7, 11, &c., passes into the bijugate 2, 4, 6, 10, &c., with no unnumbered scales, and No. 1′ of the new system as the scale of convergence. In Plate XXII. fig. 1, we have the trijugate 3, 6, 9, &c., passing into 1, 4, 5, 9, &c., with two unnumbered scales, and No. 4 of the new system as the scale of convergence; then 1, 4, 5, 9, &c., passing into 1, 2, 3, 5, 8, &c., with no unnumbered scales, and No. 4 as the scale of convergence; and, lastly, 1, 2, 3, 5, 8, &c., passing into 1, 2, 5, 7, &c., with one unnumbered scale, and No. 3 as the scale of convergence. In Plate XXII. fig. 2, we have 1, 8, 9, 17, &c., passing, as above mentioned, into 1, 2, 7, 9, 16, &c., with one unnumbered scale, and No. 6 as the scale of convergence; and 1, 2, 7, 9, 16, &c., passing into the trijugate 3, 6, 9, 15, &c., with two unnumbered scales, and No. 1 as the scale of convergence.*

With regard to the second point that I proposed to consider,—viz., as to what constitutes *affinity* of different spiral systems as regards their possible or actual derivation one from another; in other words, upon what the aptitude of different spirals to pass into one another depends,—it might, *à priori*, have been

* It might, perhaps, be possible for a mathematician to furnish a formula, whereby, from two spiral systems given, to deduce the number of ambiguous scales, and the value in the upper system of the scale of convergence, thus saving the trouble of a preliminary geometrical construction.

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imagined that resemblance in the divergence of the generating spiral would be the bond of union in cases of transition. It is manifest, however, from the instances I have given above, that although in some of the cases we find a close resemblance between the generating divergences of the two spirals between which a passage occurs,—as, for example, between $\frac{13}{34}$ and $\frac{13}{31}$,—yet much more frequently do we find the transition occurring between spirals with widely different generating divergences,—for example, between $\frac{2}{17}$ and $\frac{7}{16}$, or between $\frac{8}{37}$ and $\frac{13}{34}$. Such facts, coupled with the circumstance that in these transitions the direction of the generating spiral is very frequently reversed, and that, not unfrequently, we have a transition from a simple spiral to a conjugate or *vice versâ*, are sufficient to show that the aptitude of spirals of different systems to pass into each other is quite independent of what is ordinarily supposed to be the most essential element of a spiral arrangement, viz., the divergence of the generating spiral. On the other hand, it is to be noted that the correspondence in the numbers of the secondary spirals and verticals is always very close between the spirals which pass into one another; indeed, so much so, that the conclusion seems forced upon us, that here we have the essence of what may be called the *genetic affinity* in such cases, which may be expressed in the following terms:—that, *as regards their production or origination, spirals of different systems are to be considered as allied in proportion to the numerical correspondence of their secondary spirals and verticals.*

I shall now turn to the third and last point to be considered, viz., whether it is possible to conceive of the varying spirals in fir cones, or in other plants, being mediately or immediately derived from some one fundamental arrangement in a given set of cases. This question opens up an interesting, but I am afraid very dangerous, field of speculation. To simplify matters we may confine our attention to a few of the commoner arrangements—arrangements which may be found to prevail over an entire cone. Among such (as I have already indicated at the commencement of this paper) are the simple spirals of the ordinary system; after which the bijugate of the ordinary system and spirals of the system $\frac{1}{3}, \frac{1}{4}, \frac{2}{7}, \frac{3}{11}, \frac{5}{18}$, &c., are conspicuous; and after these the trijugate of the ordinary system and spirals of the system $\frac{1}{4}, \frac{1}{5}, \frac{2}{9}, \frac{3}{14}$, &c., may be mentioned. Have these different forms a common origin? If they have, it is in the highest degree probable that their descent from that common origin is by way of "convergence." Although admitting the occasional occurrence of *divergence* of secondary spirals, yet I am ready to agree with MM. Bravais in considering it as an improbable element in the production or derivation of the commoner forms.

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The idea which, perhaps, most naturally occurs is that the simple spiral of the ordinary system is the fundamental form; we may therefore, in the first place, look how the other forms may be derived therefrom.

(*a.*) The ordinary bijugate is derivable from the ordinary simple spiral through the intervention of the system 1, 3, 4, 7, 11, &c., thus,—

1	2	3	5	8	13
	1	3	4	7	11
		2	4	6	10

(*b.*) The system 3, 4, 7, 11, &c., is directly derivable from the ordinary system, thus,—

1	2	3	5	8	13
	1	3	4	7	11*

(*c.*) The ordinary trijugate appears to be derivable from the simple spira of the ordinary system only by way of the bijugate, and hence thus,—

1	2	3	5	8	13
	1	3	4	7	11
		2	4	6	10
			3	6	9

(*d.*) The system 1, 4, 5, 9, 14, is similarly derivable from the ordinary system by way of the bijugate, thus,—

1	2	3	5	8	13	21
	1	3	4	7	11	18
		2	4	6	10	16
		1	4	5	9	14

To the foregoing derivations the most serious objection is, that it seems improbable that the bijugate, which is the commonest of the anomalous forms, should be the result of two convergences; and still more so, that the not very rare trijugate of the ordinary system, and the also not very rare simple system 1, 4, 5, 9, 14, &c., should each be the result of three such transitions.

In the next place, let us take the ordinary bijugate and see how the other systems may be derived from it.

(*a.*) The ordinary simple system is derivable by convergence from the bijugate only, it would seem, by way of the system 1, 4, 5, 9, &c., thus,—

	2	4	6	10
	1	4	5	9
1	2	3	5	8

* It will be remembered that in Cone III. the system 1, 2, 5, 7, 12, &c., is derived from the ordinary system by coalescence of consecutive scales in one of the secondary spirals by 5. Here, the system 1, 3, 4, 7, 11, &c., would be derived from the same by coalescence of consecutive scales in one of the secondary spirals by 3.

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This derivation is highly improbable, and, indeed, quite inadmissible; although it is interesting to note that in Cone III. (see diagram in Plate XXII. fig. 1), a spiral $\left[\frac{13}{34}\right]$ of the ordinary system is actually derived from the system 1, 4, 5, 9, &c. Failing this derivation, we may ask if it is possible for the ordinary simple system to be derived from the bijugate by abortion of one-half of the scales? At first sight this derivation seems, and perhaps is, much more improbable than the first one. In the very remarkable cone, however, described above, and figured in Plate XIX. fig. 3, a process of abortion of this kind, arrested half way, seems to have occurred. In looking at the lower part of this cone, it is quite apparent that had the large and small scales been developed equally we should have had a bijugate arrangement. It is just conceivable, however, that these small scales may be the result of a "superfœtation" (to borrow MM. Bravais' very obstetrical term); but this does not seem at all probable. The derivation by abortion would, of course, be represented thus,—

2	4	6	10	16
1	2	3	5	8

(*b.*) The system 1, 3, 4, 7, 11, &c., is derivable from the ordinary bijugate only by way of the simple spiral of the ordinary system, and this may be done by either of the methods indicated under the last head.

(*c.*) The ordinary trijugate, as already indicated, is directly derivable from the bijugate, thus,—

2	4	6	10
	3	6	9

(*d.*) The system 1, 4, 5, 9, &c., is also directly derivable from the bijugate of the ordinary system, thus,—

2	4	6	10
1	4	5	9

In looking at the two foregoing schemes of derivations, it is evident that the great difficulty lies in the absence of any probable derivation, either of the ordinary bijugate from the ordinary simple spiral, or conversely, of the ordinary simple spiral from the bijugate. As to the other systems, it is evident that 1, 3, 4, 7, 11, comes most naturally from the simple ordinary spiral; while the ordinary trijugate and the system 1, 4, 5, 9, 14, are most readily derived from the ordinary bijugate. At one time I was inclined to accept the bijugate as the fundamental form;* but the more I reflect on the matter, the more I am con-

* This view I published (under reserve) in the abstract of this communication in the Society's Proceedings, vol. vii. p. 453.

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vinced of the futility of the endeavour to derive the different forms from one origin. Indeed, we seem almost compelled to *recognise both the ordinary simple spiral and the ordinary bijugate as fundamental forms*, i.e., *forms with either of which a cone may commence without the intervention of another*; and if this be done, the derivation of the various systems from the one or from the other would be a very simple matter.

Before concluding, I would submit a tabular analysis of the five flower-spikes of *Banksia occidentalis*, already brought under the notice of the Society, but which may very profitably be reconsidered in connection with the above communication.

Tabular Analysis of five flower-spikes of Banksia occidentalis *in Museum of Economic Botany, Royal Botanic Garden, Edinburgh.*

One, with	—	—	—	7	7	$14 = \frac{1}{2 \times 7}$
Two „	—	—	1	6	7	$13 = \frac{2}{13}$
One „	—	1	2	5	7	$12 = \frac{5}{12}$
One „	1	2	3	5	8	$13 = \frac{5}{13}$

I shall not stop to inquire from what one or more fundamental forms these may be derived, but it is very interesting to note how, among these forms, we have spirals of the most widely different fundamental divergences, closely resembling each other in the number of their secondary spirals and verticals, just as we have seen above in the case of the fir cones.

It is possible that, in ignorance, I have gone over ground which has been trodden before; for example, I have not had access to any of SCHIMPER'S works on phyllotaxis. However, as it is in the highest degree improbable that the abnormal forms above described should repeat themselves, I rest assured in the belief that I have contributed at least new, if not valuable matter.

In conclusion, I would specially thank my friend Professor TAIT for the many valuable suggestions I have received from him in the course of this work, and for his patience and readiness in assisting me when in any difficulty.

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EXPLANATION OF PLATES XIX., XX., XXI., XXII.

[In Plate XIX. the figures are drawn on stone from photographs.

In Plate XX. the figures are photo-lithographic reductions from outlines made in the following manner:—Photographs of the cones were obtained (the cones having been previously painted of a uniform grey colour), and on these the outlines were carefully gone over with a steel "crow-quill" and Indian ink. This done, the photographs were then *washed out* with a solution of Cyanide of Potassium (about 5 grains to the ounce of water); the outlines drawn remaining, but now, of course, on white paper. These outlines, after being retouched and intensified with Lamp-black, and receiving the addition of the numbers, were then photo-lithographed to the scale required, and colour added by chromo-lithography. I have thought it worth while to record the above process, as it may be found to be very useful in many cases where an accurate outline of a given object is required.

The diagrams in Plates XXI. and XXII. are photo-lithographic reductions from drawings on a larger scale.]

Plate XIX.

Figure 1. Cone II.; about natural size. The two secondary spirals by 7, which converge into one of a double set by 3 at the top, are distinguished by being shaded of a lighter tint than the others. The scale of convergence is obviously double.

Figure 2. Cone III.; somewhat magnified. Here, as in the last case, the scale of convergence near the top of the cone is obviously double.

Figure 3. Cone V.; somewhat magnified. Showing the small scales intercalated among the larger ones towards the lower part of the cone.

Plate XX.

Figures 1 and 2 represent different aspects of Cone I.; considerably reduced. In fig. 1, two secondary spirals by 9, coloured red, are seen to converge into one by 8, which is continued to the top of the cone. In fig. 2, two secondary spirals, coloured blue, in a double set by 7, are seen to converge into one by 13, which is continued to the top of the cone. See diagram in Plate XXI. fig. 1.

Figure 3. Cone II.; considerably reduced. The same view as that in Plate XIX. fig. 1. Two secondary spirals by 7, coloured red, are seen to converge into one of a double set by 3. The scale of convergence is obviously double. See diagram in Plate XXI. fig. 2.

Figures 4 and 5. Different aspects of Cone III.; about naturalsize. Fig. 4 is the same view as that in Plate XIX. fig. 2. Two secondary spirals, coloured blue, in a triple set by 2, converge into one by 5, which is continued to the top of the cone. Of the three secondary spirals by 9, coloured red, the two uppermost converge into one by 8; which last, and the lowermost of the aforesaid three, converge in their turn into one by 7. The last scale of convergence (coloured purple from the blue and red spirals happening to cross) is, like that near the top of Cone II., obviously double. See diagram in Plate XXII. fig. 1.

Figures 6 and 7. Different aspects of Cone IV.; considerably reduced. In fig. 6, two spirals by 8, coloured red, about the middle of the cone, are seen to "diverge" from a single one at the base. In fig. 7, two secondary spirals by 8, coloured red, converge into one by 7; while, higher up, two of the spirals by 7, coloured blue, converge into one of a triple set by 2. See diagram in Plate XXII. fig. 2.

Figure 8. Cone, from Museum of Economic Botany, Royal Botanic Garden, Edinburgh; considerably reduced (natural size $4\frac{1}{3}$ inches). The arrangement in the lower part of this cone is somewhat confused, and has not been determined. From about the middle, however, up to the top, a regular $\frac{5}{13}$ spiral (series $\frac{1}{2}$, $\frac{3}{8}$, $\frac{8}{21}$, $\frac{13}{34}$, &c.) is exhibited. As has been pointed out by MM. Bravais, this system is readily derivable by convergence from the system 1, 4, 5, 9, 14, &c.

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Figure 9. Cone, from Mr Smyth, Emyvale; considerably reduced (natural size $4\frac{1}{2}$ inches). This cone exhibits a very regular spiral of the series $\frac{1}{1}$, $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, &c. It will be seen that the lines by 37 are scarcely vertical, so that the spiral has probably the divergence $\frac{13}{34}$.

[Plates XXI. and XXII. The diagrams or plans here hardly require explanation. The regions exhibiting the different spiral arrangements are marked off from each other by horizontal lines projecting laterally at the level where each new system commences; the arrangement in each region being indicated by a fraction alongside of it. I have marked the "scales of convergence" with their number in the upper of the two systems in the respective cases; adding, within brackets, the numbers of the actual or presumed components of these scales according to the spiral of the lower system,—the actual without, the presumed with, a mark of query.]

Plate XXI.

Figure 1. Diagram of Cone I. It will be noted that here, in order to save room, the uppermost spiral is carried up only to No. 36 of the 106 or 107 scales in the corresponding region of the cone.

Figure 2. Diagram of Cone II.

Plate XXII.

Figure 1. Diagram of Cone III.

Figure 2. Diagram of Cone IV.

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FIG. 3.

FIG. 2.

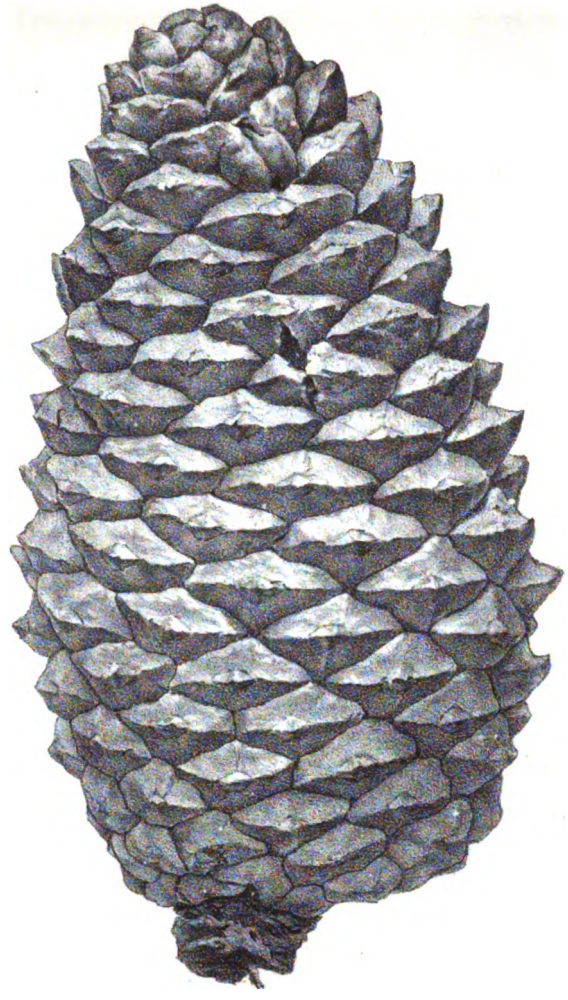

FIG. 1.

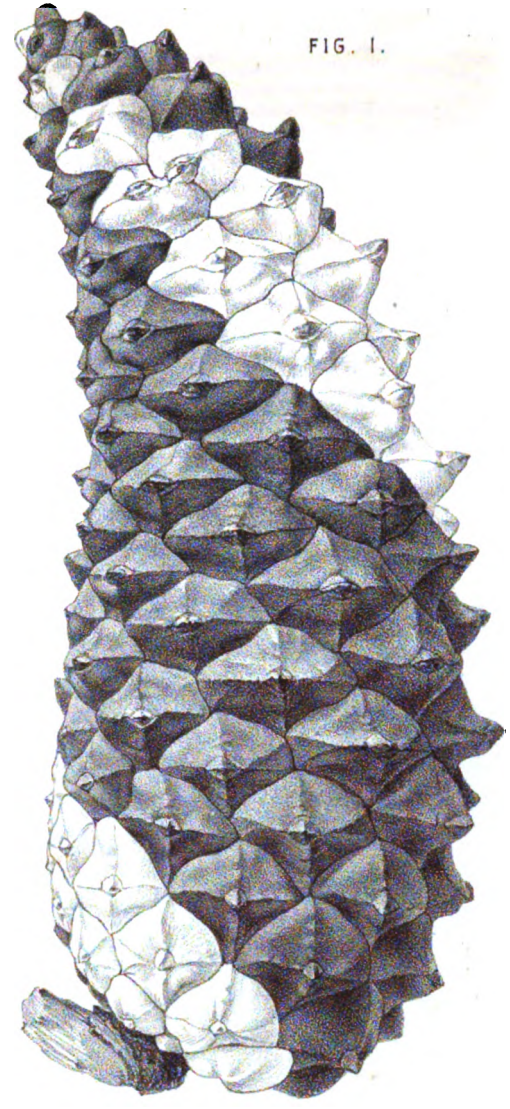

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Fig. 1.

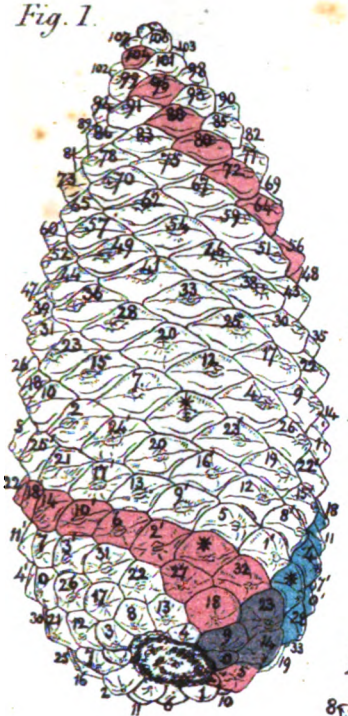


Fig. 6.

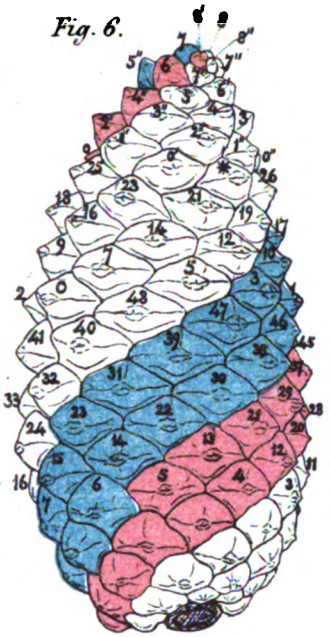


Fig. 7.

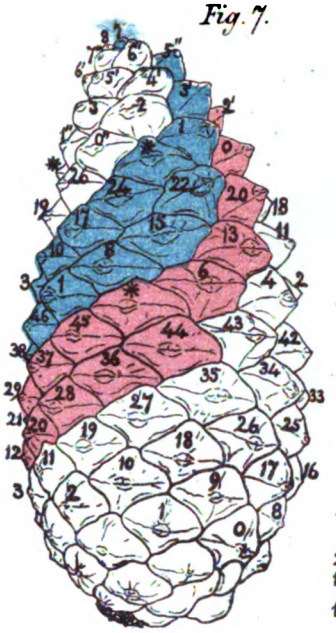


Fig. 2.

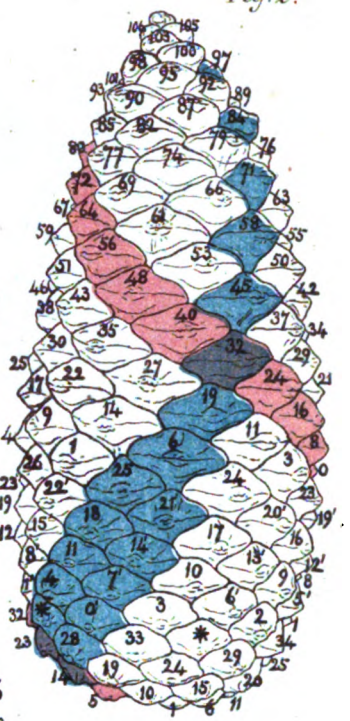
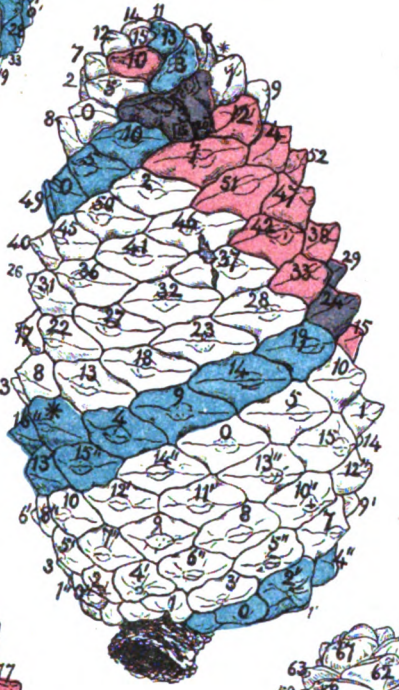


Fig. 4.



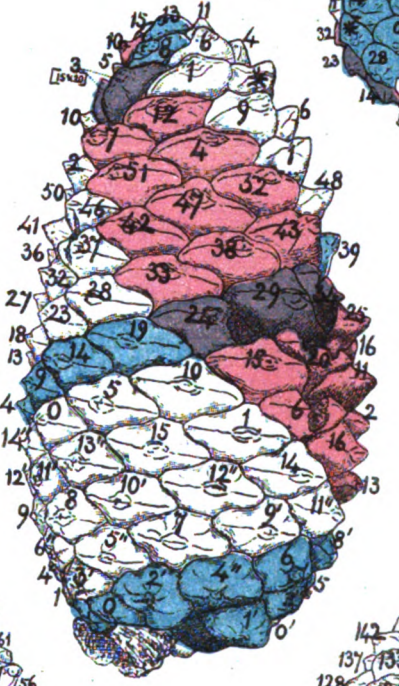
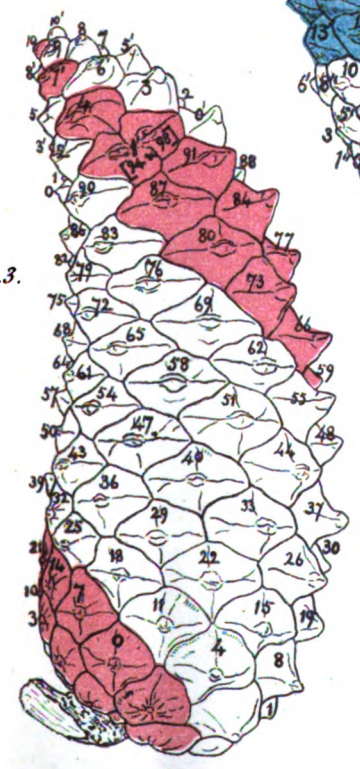


Fig. 5.

Fig. 3.



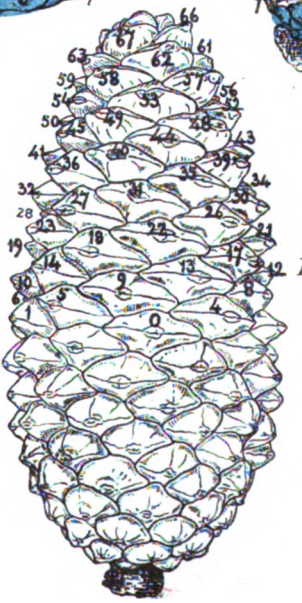


Fig. 8.

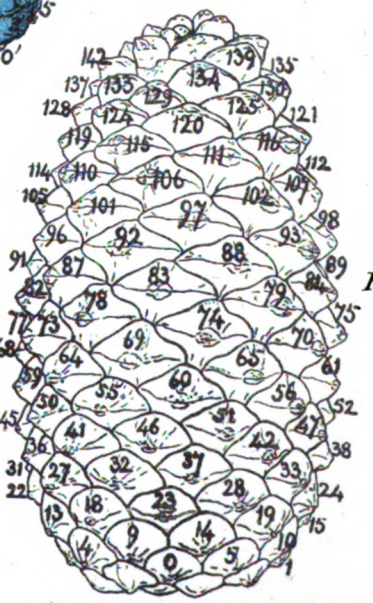


Fig. 9.

Drawn (from Photographs) by A. Dickson, M.D.

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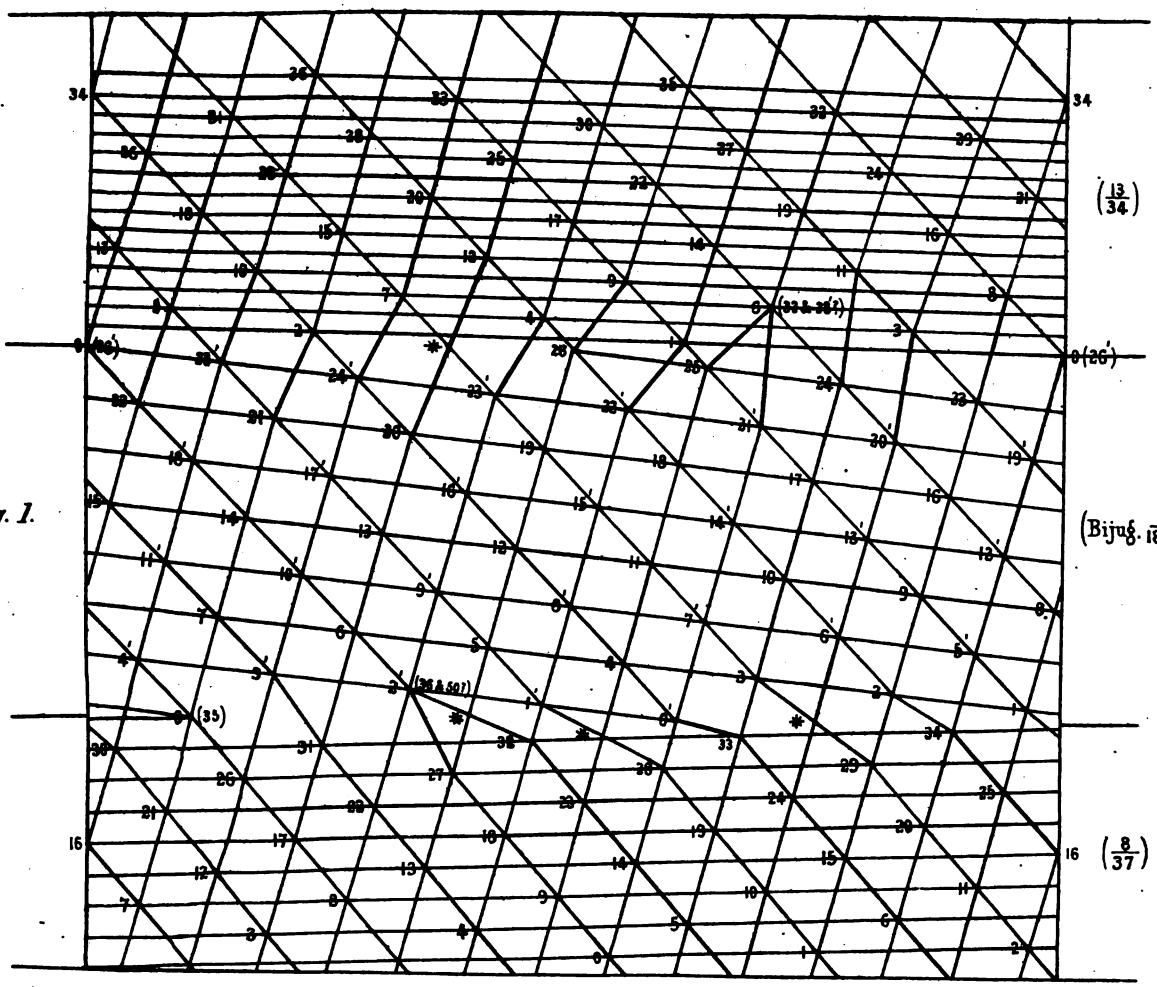

Fig. 1.

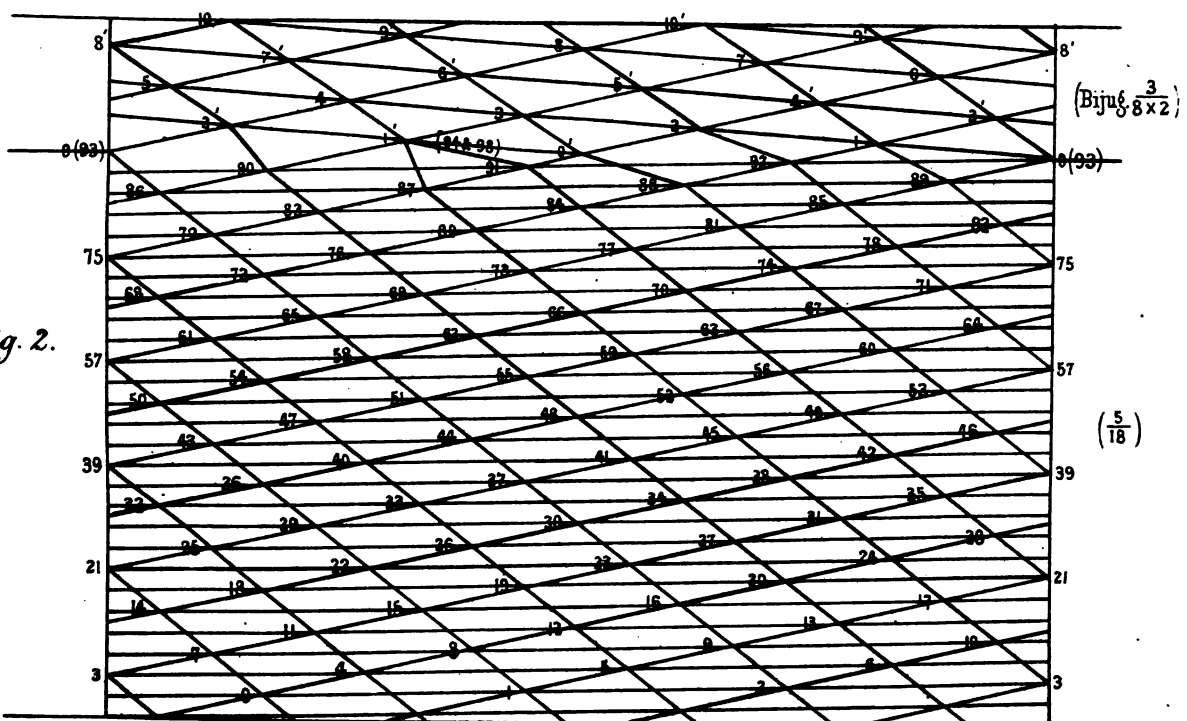

Fig. 2.

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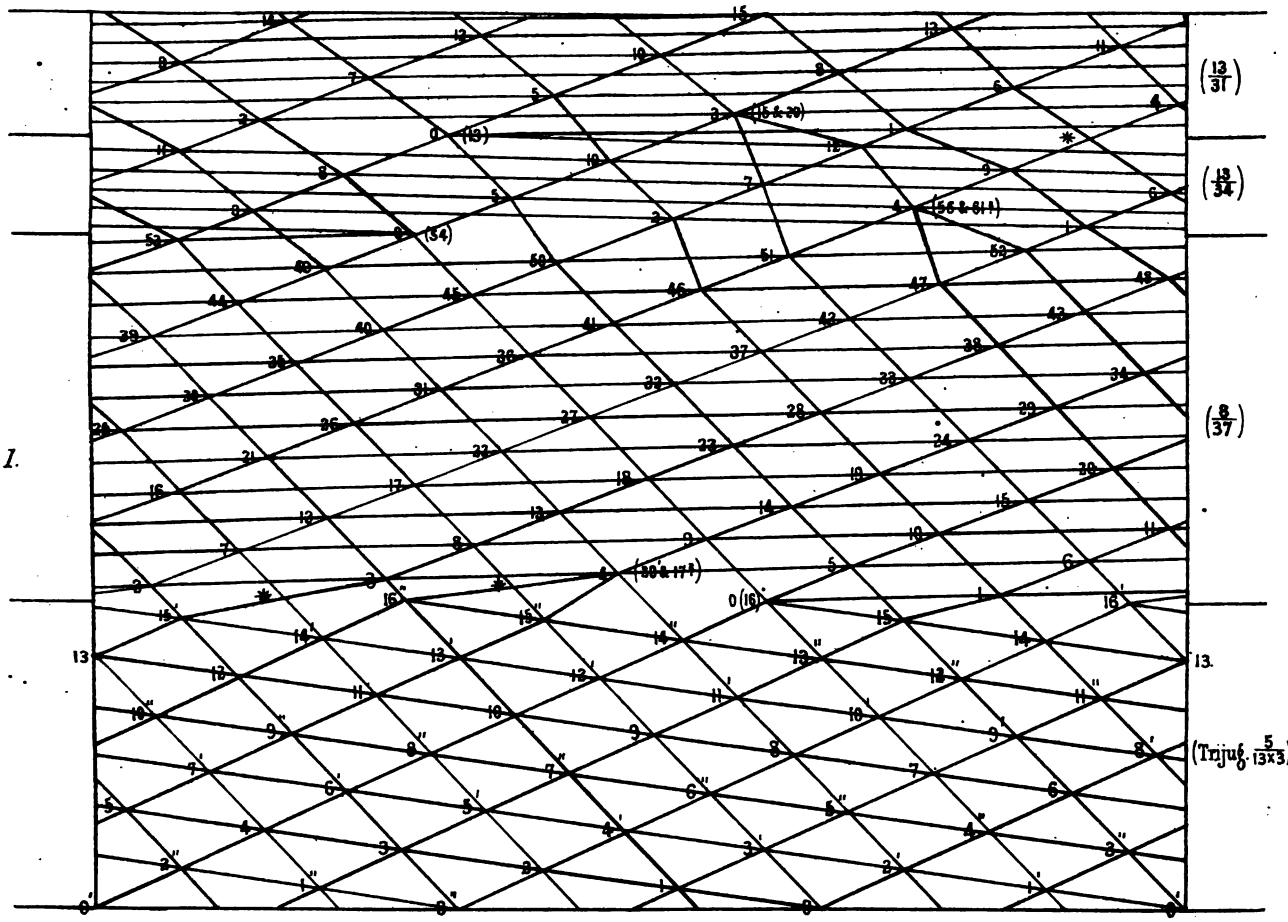

Fig. 1.

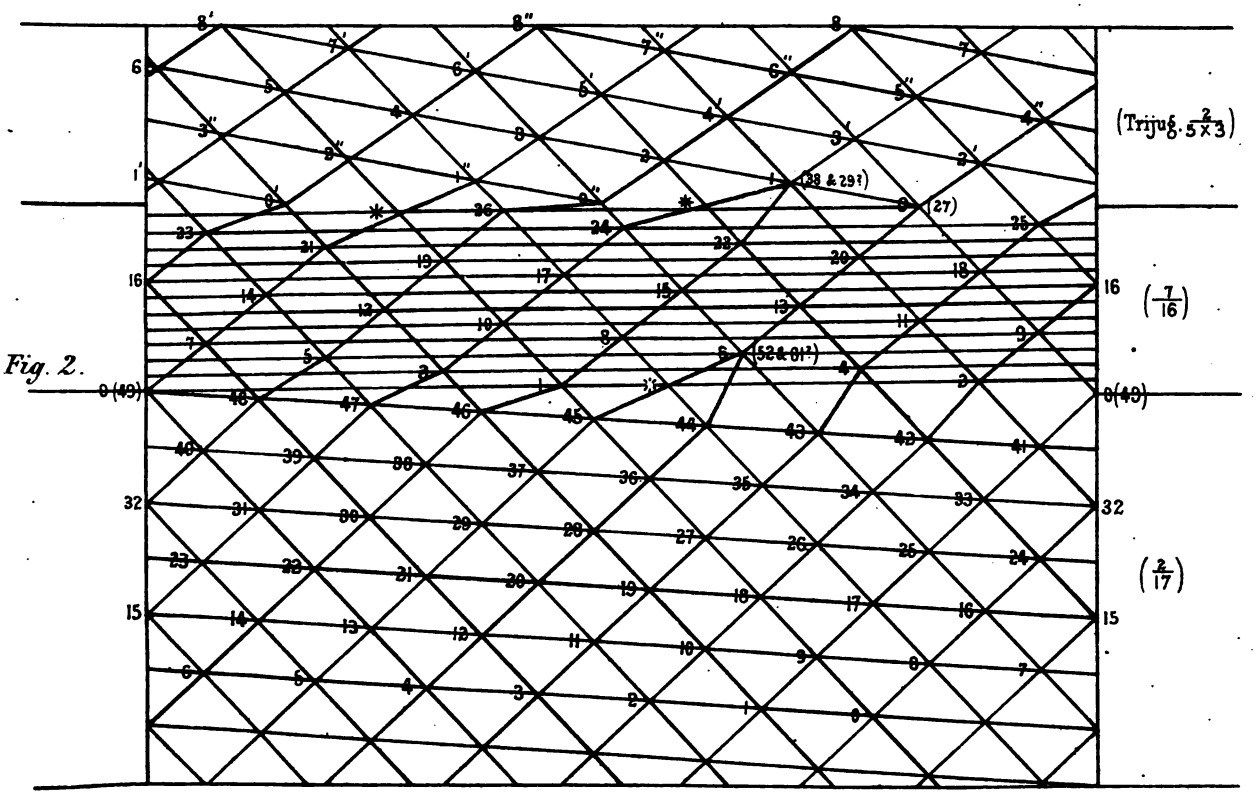

Fig. 2.

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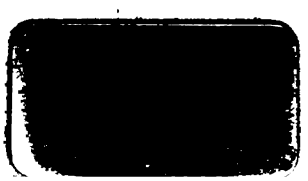

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